COARSE AGGREGATE GRADATIONS FOR P.C. CONCRETE

Final Report
For
MLR-94-8

April 1995

Project Development Division

Iowa Department of Transportation

Final Report for MLR 94-8

COARSE AGGREGATE GRADATIONS FOR P.C. CONCRETE

by

Chengsheng Ouyang
515-239-1088

Office of Materials
Project Development Division
Iowa Department of Transportation
Ames, Iowa 50010

April 1995

TABLE OF CONTENTS

Disclaimer

1. Introduction

The current gradation bands for concrete coarse aggregate in Iowa have been used for many years. A historical review on the development of the coarse aggregate gradations has been given by Moussalli[1]. However, contractors recently tend to supply aggregates on the coarser side of the allowed band because producers remove 3/8" and down chips from their concrete stone to sell to other markets. The 3/8" chips we supplied from Linwood mine were removed from the concrete stone to make asphalt concrete. This results in gap gradations for the aggregate. The objective of this project is to determine if the gradation bands for the various sieve sizes should be modified.

2. Materials and Mix Proportions

Two gradations (listed in Table 1) were tested, and corresponding mixes are given in Table 2. Iowa Department of Transportation Standard Mix C-3 and Aggregate Gradation No. 3 were selected as the reference. C-3 proportions were used for mixes #1 and #2. C-3 mix with 10% reduction of the cement content was used for mix #3. C-3 mix with 20% reduction of the cement content was used for mix #4.

Mix #1 used a concrete stone from Linwood (No. A82008), Scott County. Mixes #2, #3 or #4 used a coarse aggregate mix of 65% concrete stone and 35% 3/8" chips from the same source. The sand used was from Anderson, Popejoy, Flanklin County.

R11Z cement (blend) was used for the all mixes.

3. Experimental Program

For each mix listed, eighteen beams and nine cylinders were cast, and these beams were used for measuring moduluses of rupture (MOR) under center-point loading and third-point loading, respectively. A total of seventy two 6" x 6" x 20" concrete beams and thirty six 4.5" x 9" concrete cylinders were made. These cylinders were used for determining compressive strength. Slump and entrained air contents were taken on the batched concrete a ıd water/cement ratios were compared.

Six beams (three for center-point loading, the other three for third-point loading) and three cylinders were tested for each mix at 7, 14 and 28 days for flexural and compressive strengths respectfully. The specimens were kept in the 100% humidity, 73°F curing room until tested. All experimental results were given in Table 2.

4. Results and Discussion

Average values of MOR-CPL (center-point loading), MOR-TPL (third-point loading) and f'_c (compressive strength) experimentally measured are plotted against specimen age in Figures 1, 2 and 3, respectively. All measured values of the strengths increase with increasing specimen age. As expected, for the same mix values of MOR-CPL are generally greater than values of MOR-TPL.

<u>The effect of cement content</u>: Mixes #2, #3 and #4 use the same aggregate gradation but have different cement contents. Mix #2 uses C-3 mix which contains 603 lb cement per cubic yard of concrete. Mixes #3 and #4 have 10% and 20% reduction from the C-3 mix, respectively. As seen in Fig. 4, all measured strengths decrease with decreasing cement content.

To achieve 2.0 in. of slump, Mix #2 requires a water/cement ratio of 0.481 (see Table 2), whereas Mix #3 requires a water/cement ratio of 0.521. This indicates that the required water/cement ratio increases with decreasing cement content.

The effect of chip replacement: Mixes #1 and #2 use the same materials except that 35% of the coarse aggregate is replaced by 3/8" chips for Mix #2. It is seen from Fig. 5 that while the chip replacement leads to greater values of MOR-CPL and MOR-TPL up to the age of 14-day, these MOR values at the age of 28-day remain almost identical. On the other hand, the chip replacement increases the compressive strength up to the age of 28-day.

As shown in Figs. 1, 2, and 3, Mixes #1 and #3 have comparable strengths at different ages. This indicates that when 35% of coarse aggregate is replaced by 3/8" chips, one could reduce cement factor 10% and achieve equivalent strengths.

All the mixes have good workability. Visual examination on broken surfaces of failed specimens indicates that all the specimens have good coatability for aggregates.

5. Conclusion

Strengths of portland cement concrete decrease with decreasing cement factor. On the other hand, 35% of chip replacement for coarse aggregate increases strengths of concrete. By replacing 35% of coarse aggregate with chips, one could reduce cement factor 10% and achieve equivalent strengths.

6. References

1. Moussalli, S., "Coarse Aggregate Gradation for Use in P. C. Concrete," Iowa Department of Transportation, Internal Report, 1994, 15.pp.

Table 1 Test Programm (% passing)

Test No.	37.5 mm (1.5")	26.5 mm (1.06")	19.0 mm (0.75")	13.2 mm (0.53")	9.5 mm (0.375")	4.75 mm (#4)	2.36 mm (#8)	75 m (#200)
1	100	99	71	37	9.0	0.9	0.6	0.3
2, 3 & 4	100	99	81	59	38	1.0	1.0	0.3
*	100	95-100		25-60		0-10	0-5	1-1.5

* Gradation No. 3

Table 2 Summary of Experimental Results

Mix No.	Cement content (lb/cu yd)	Slump (in.)	w/c	Air content (%)	Age (days)	Average strength (psi)		
						MOR-CPL	MOR-TPL	f'_c
# 1	603	2.5	0.467	6.0	7	690	590	3600
					14	810	640	3940
					28	860	730	4530
# 2	603	2.0	0.481	7.0	7	770	680	4320
					14	830	700	4760
					28	860	720	5470
# 3	542.7	2.0	0.521	6.4	7	700	610	3850
					14	820	700	4310
					28	860	750	5100
# 4	482.4	2.25	0.572	6.2	7	710	610	3550
					14	770	670	4200
					28	830	680	4570

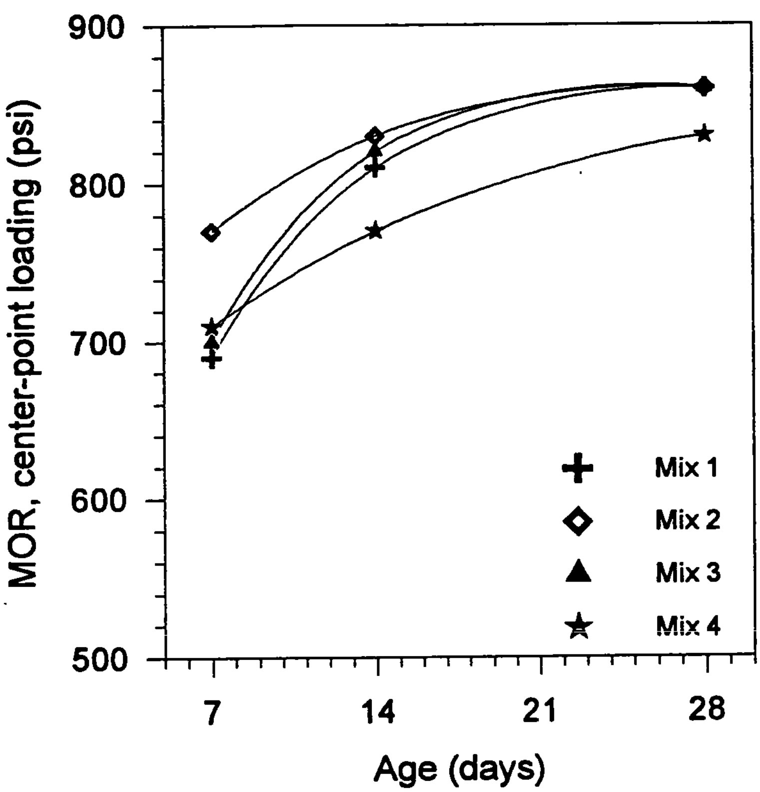

Fig. 1 Relationship between MOR and specimen age
(Center-point loading)

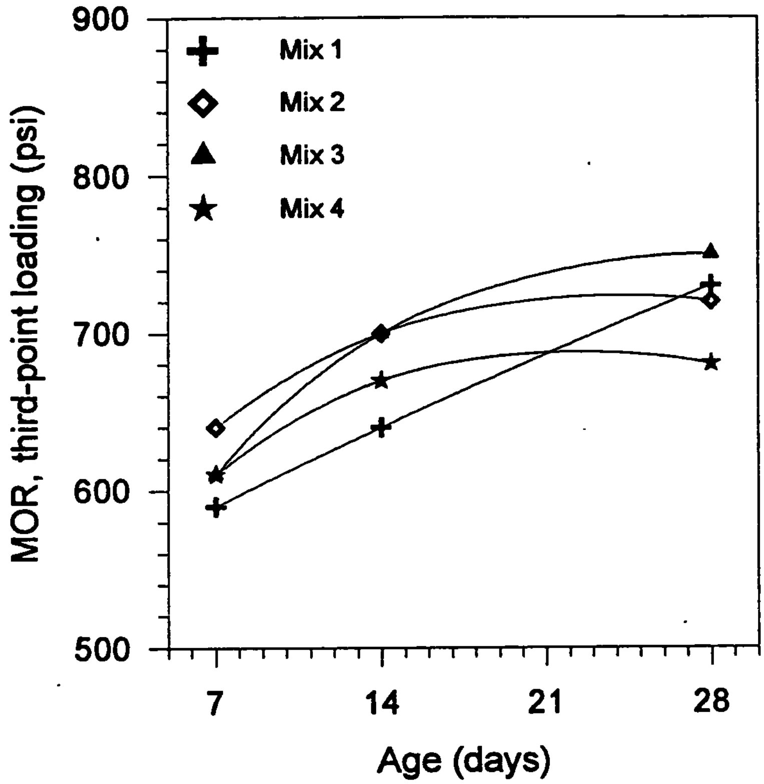

Fig. 2 Relationship between MOR and specimen age
(Third-point loading)

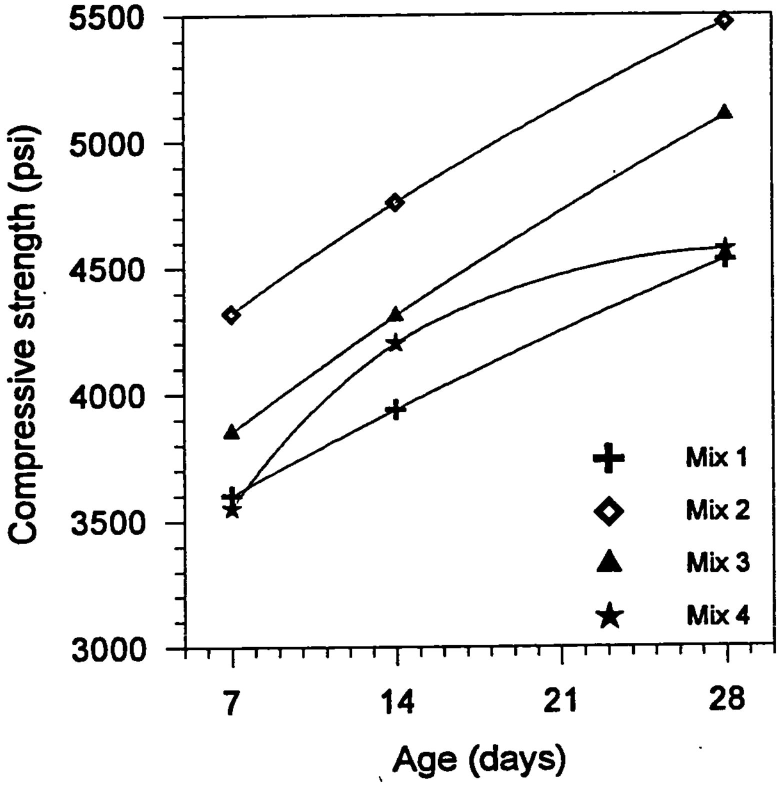

Fig. 3 Relationship compressive strength and specimen age

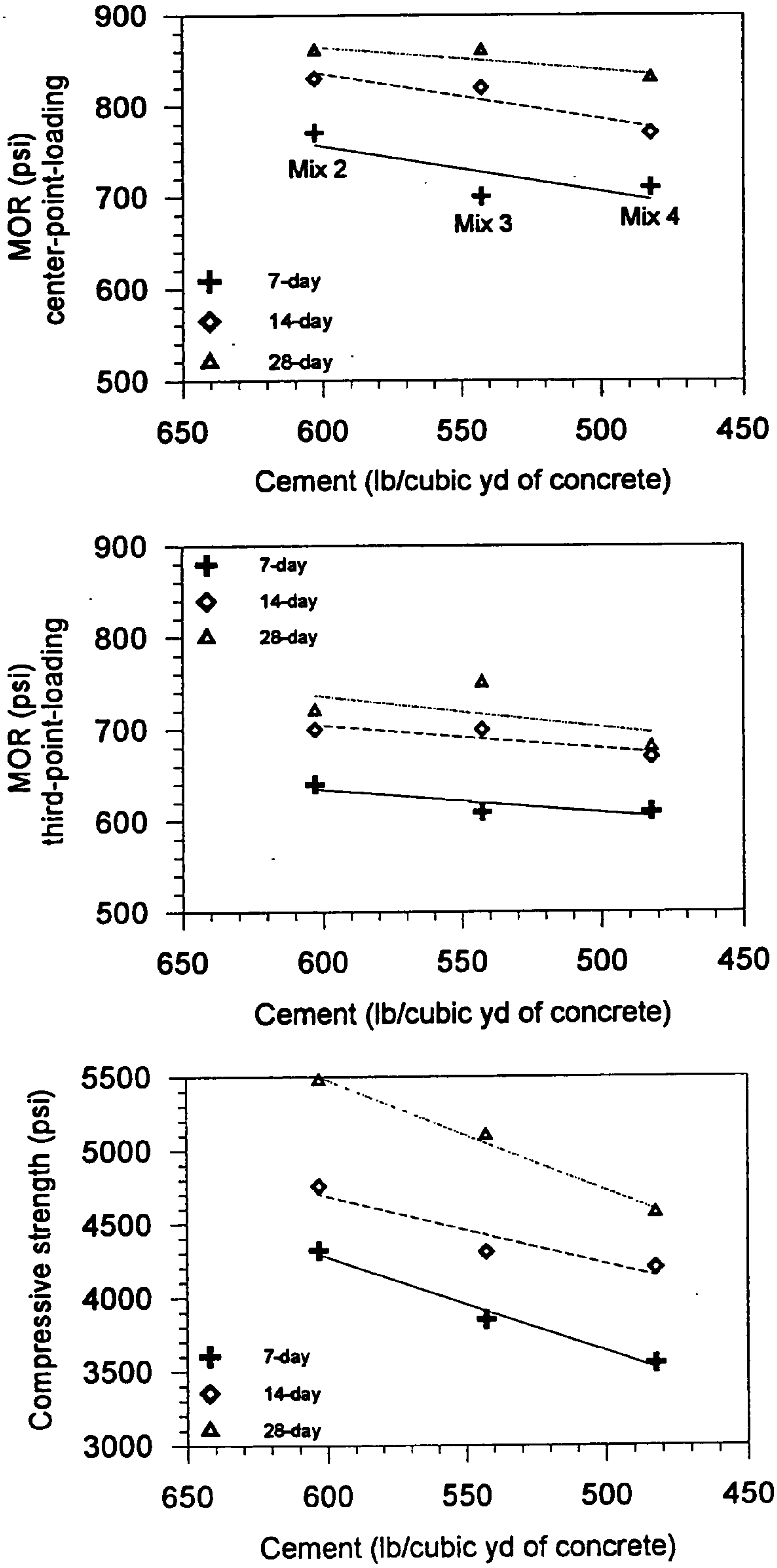

Fig. 4 Effect of cement content on strength development

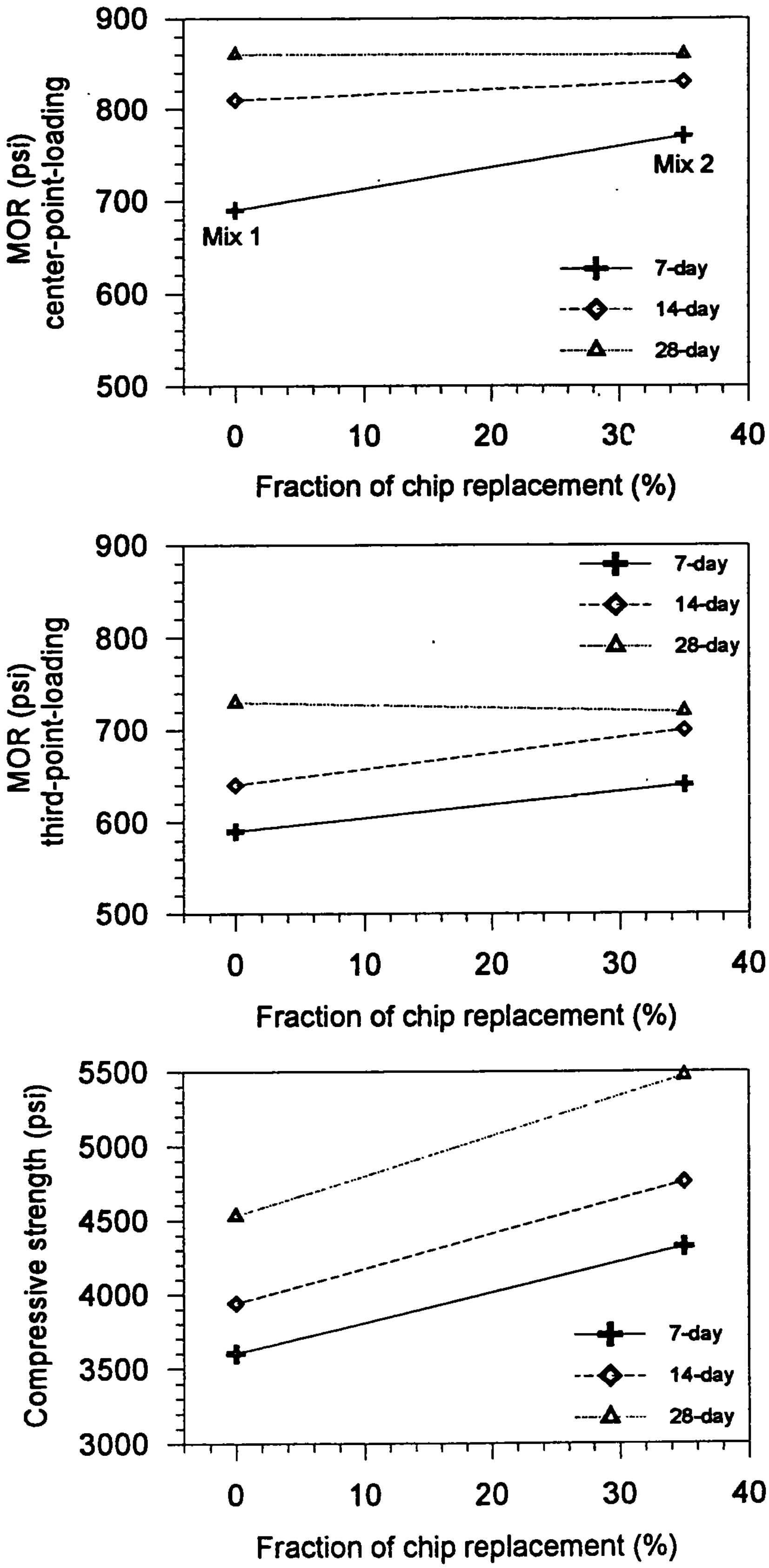

Fig. 5 Effect of chips replacement on strength development